WILLINGNESS -TO-PAY FOR BIG SCIENCE:

EVIDENCE FROM A CONTINGENT VALUATION SURVEY CONCERNING THE LARGE HADRON COLLIDER (CERN)

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Abstract

An increasing number of governments fund large-scale basic research infrastructures. Discoveries expected in such Big Science projects often do not have any known use-value. The general public, however, has a cultural interest in science (revealed e.g. by large number of visitors of research facilities and their websites). We want to study the willingness-to-pay (WTP) for basic research by the general public, in analogy with the empirical study of the non-use value of some environmental and heritage goods. We focus on the Large Hadron Collider (LHC) at CERN (Geneva, Switzerland), the largest particle accelerator worldwide, where in 2012 the Higgs boson was discovered. Nobody knows the practical value of such discovery, beyond pure knowledge per se. Our study is based on a contingent valuation (CV) survey of 1,022 undergraduate students enrolled in more than 30 different degrees at five universities located in four countries (France, Italy, Spain, UK). We ask two main research questions: which are the determinants of the WTP for the LHC discoveries? What is the average contribution that the respondents would be willing to pay for such discoveries? Survey results suggest some possible drivers of WTP for Big Science and reveal a positive WTP also by students in the humanities and social sciences, around two thirds of our sample.

Keywords: Research infrastructures, Cost-benefit analysis, Non-Use Value, Existence value, Contingent Valuation, Large Hadron Collider

JEL Codes: C83, D61, I23, O32

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1 Introduction

In the last decades, an increasing number of governments and institutions have supported basic research defined by OECD (2002) as 'experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view'. In the near future, several and ambitious projects are at stake. The 'Europe 2020' strategy includes the Innovation Union flagship initiative, aimed at transforming the EU area into a world-class science performer by completing or launching the construction of priority European RIs (European Commission, 2010). Within this framework, the self-regulatory body European Strategy Forum on Research Infrastructures (ESFRI) aims at developing a joint vision and a common strategy including updated roadmaps, reports and criteria as tools for planning and implementing new pan-European RIs.[1] After the demise in 1993 of the Superconducting Super Collider (SCC) in the US[2], the European Organization for Nuclear Research (CERN) in Geneva has achieved the leadership in particle physics thanks to the LHC, where the Higgs boson was discovered in 2012. Recently, the CERN has also launched a study for the Future Circular Collider (FCC), laying the foundations for the post-LHC era (Reich, 2013; Banks, 2014).[3] Other countries, including Japan and China, are planning large-scale scientific ventures for the next decades.[4]

These Big Science projects are indeed very costly. In 1993, the US Congress abandoned the SSC project because of an increase in the estimated costs from 4.4 billion USD to 12 billion USD.[5] The present value to 2025 of the LHC costs (excluding scientific personnel in the more than one hundred associated universities) is around 13.5 billion EUR (Florio et al. 2016). Is it worth for the taxpayers to fund such projects? The question is particularly intriguing when basic research is considered, since its above-mentioned definition acknowledges that it has yet 'no use'.

In the traditional perspective of welfare economics, the value of a good arises from its use, or utility. Nevertheless, since the Sixties environmental economists have been arguing that there may be a value arising from its non-use, including the pure existence of the good itself (Weisbrod 1964; Krutilla 1967). Bateman et al. (2002) classify the non-use value into three main categories: the bequest value, the option value and the existence value; in some cases the notion of quasi option value is added to the list (Boardman et al. 2001). The option value arises when it is possible to predict some use of the good in the future but there is not yet a use at the present time. If the future use of the good is not known yet or it is today unpredictable, and there is irreversibility, then the notion of quasi-option value has been proposed.[6] Differently from bequest (or altruism), option and quasi option values, the existence value originates from the utility that arises from the mere perception of the existence of the good, even in the absence of any expected or unpredictable use (Walsh et al. 1984; Brun 2002). Several studies worldwide provide empirical estimations of the existence value of environmental goods (among others, Heafele et al. 1991; Chopra 1993; Echeverria et al. 1995; Loomis et al. 1996; Costanza et al. 1997; White and Lovett 1999; Amirnejad

[1] See for details http://ec.europa.eu/research/esfri

[2] See http://www.scientificamerican.com/article/the-supercollider-that-never-was/

[3] The FCC will be a proton-colliding machine more powerful and larger (80-100 km circumference) than the LHC. It would still be based near Geneva and would use the LHC as its injector. Preparatory studies are on-going and a conceptual design study is likely to be ready by 2017. For further details see fcc.web.cern.ch

[4] See, for example, the proposed Circular Electron Positron Collider program (see cepc.ihep.ac.cn)

[5] Giudice (2010); Baggott (2012)

[6] For further details on the notion of the non-use value including the concept of bequest value, option value and quasi-option value see Brookshire et al. (1983), Johansson (1983), Bateman et al. (2002), Boardman et al. (2001).

et al. 2006). During the last twenty years, the concept of existence value has been transferred to cultural economics (Hansen 1997; Frey 2000; Alberini et al. 2003; Alberini and Longo 2006; Packer 2008; Marsh et al. 2010; Fujiwara 2013).[7]

Following this previous literature, Florio and Sirtori (2015) and Florio et al. (2016) suggest that the notion of existence value can be extended to the RIs, and, in general, to basic science as well. Specifically, the authors argue that there may be a public preference for 'curiosity-driven' new knowledge per se, and as a consequence, the existence value of RIs should arise from the pleasure (or utility) of knowing that something may be discovered, hence its existence is revealed, even if there is no predictable use of it. If so, there is an analogy between scientific discoveries and environmental goods: the only difference is that natural environments are something that are known to exist and that may be endangered, while a discovery reveals something that already exists in nature, but was previously unknown.

The non-use value of RIs may justify, to a certain extent, the governments' support to basic research, but little is known about the intensity of public preferences in this area. How much are people willing to pay for science? What are the rationales behind this preference? This paper provides some possible answers to these questions by using a contingent valuation (CV) experiment (Blomquist and Whitehead, 2006).[8] Specifically, the objective of this research is twofold:

1. To grab those factors affecting individual preferences (socio-economic and cultural characteristics) for the LHC research; that is for a scientific project providing discovery as a pure public good;
2. To quantitatively estimate the non-use value of the LHC by assessing how much the general public is willing to pay for its discovery potential.

As stated by Johansson and Kriström (2015, p. 24): "If the project being evaluated affects non-use values, this should be reflected in the cost-benefit analysis". Thus, it seems interesting to examine the WTP for scientific discovery, even when, as in the case of the Higgs boson, nobody knows what its use might be.

The paper is structured as follows. Section 2 briefly describes the LHC as a provider of scientific discovery. In Section 3, we discuss the theoretical framework and the CV survey. Data and descriptive statistics are presented in Section 4. Section 5 examines the determinants of the empirical willingness-to-pay (WTP) by applying both binomial and polychotomous logistic models; afterwards the estimation of the individual WTP in our sample is provided. Section 6 concludes with a discussion and suggestions for further research in this potential new area of CBA.

2 Context: The Large Hadron Collider (LHC)

The LHC is the world's largest and most powerful particle accelerator, built on behalf of the CERN from 1994 to 2008. It is located near Geneva, in a 27-kilometre tunnel, one hundred meters underground, beneath the border between France and Switzerland.

The LHC hurls beams of protons and ions at a velocity approaching the speed of light, steered by means of superconducting magnets along with a number of accelerating devices. The high-energy particle beams run in opposite directions in separate pipes and the LHC causes the beams to collide

[7] Pagiola (1996) clarifies the notion of option value, quasi-option value and existence value in the context of cultural economics.

[8] As far as we are aware, Florio et al. (2016) is the first study that attempted to calculate the willingness to pay (WTP) for the LCH by using a cost-benefit analysis approach, albeit different from the present one.

with each other at four locations around the accelerator, each corresponding at the positions of four particle detectors: ATLAS, CMS, ALICE and LHCb. Here, the resulting events caused by the collision are recorded. Collisions are examined to find answers to many issues left unsolved by the Standard Model of particles and forces[9] such as the origin of particles' mass, a coherent explanation of the interactions between the fundamental forces of the universe and the phenomena responsible for dark matter. The LHC should also help to investigate some issues related to the share of matter and anti-matter in the universe.

On 4 July 2012, the ATLAS and CMS experiments announced the discovery of a new particle consistent with the Higgs boson predicted by the Standard Model, adding, in this way, a new piece to our knowledge of nature.[10] In the next years, investigations of the properties of the Higgs boson as well as the possible discovery of new particles are expected to shed light on the current theory of fundamental interactions and on the puzzle about the origin of the universe.

Since its construction phase, the LHC has attracted great interest from the general public. From 2004 (when the LHC was opened to visitors) to 2013, 418,200 people visited the LHC, reaching a peak of about 100,000 visits per year in the aftermath of the announcement of the Higgs boson discovery.[11] The travelling exhibitions related to the LHC have attracted 344,000 visitors worldwide to 2013. In the same period, the users of LHC-related social media (YouTube, Twitter, Facebook and Google+) amounted to around 2,010,000; while the number of CERN-LHC website visits was more than 37 million. These figures are expected to further increase in the near future (Florio et al., 2016). These figures suggest that the LHC has a cultural impact on the general public, which should be analyzed separately from its scientific impact.

The focus of our paper is specifically about the interplay between basic science and its perception by citizens outside the scientific community. In fact the general public indirectly supports science through taxation. The CERN is entirely funded by transfers by its Member States, but little is known about the willingness-to-pay for large scale RIs.

3 Relevant literature and analytical framework

The approach used in this study to estimate WTP for the LHC is contingent valuation, the most common and well-established approach to estimate non-use values (Davis 1963; Mitchell and Carson 1989; Carson and Groves 2007). A standard reference for CV studies are the guidelines provided by Arrow et al. (1993), that have then been extensively refined, adapted and implemented to estimate the non-market value of public goods, particularly environmental, health and cultural goods (Carson et al. 1996; Hansen 1997; Whitehead and Hoban 1999; Thompson et al. 2002; Venkatachalam 2003; Polome et al. 2006; Carson and Groves 2007; Carson, 2012).

In order to elicit the respondents WTP for a given good, the NOAA guidelines suggest to use a referendum-like approach[12] according to which, people should be asked to state only '*yes*' or '*no*' to the proposed bid. Hanemann (1984) and Carson (1985) have stressed the importance of follow−up questions addressed to estimate the maximum WTP value. The bid level offered in the follow−up

[9] To further details on the main goals of the LHC and on a non-physicists understandable version of Standard Model of particles and forces see the LHC guide available at http://cds.cern.ch/record/1165534/files/CERN-Brochure-2009-003-Eng.pdf

[10] The Higgs mechanism may shed light on the mass of particles, and may explain why some particles are very heavy while others have no mass at all. According to the Higgs mechanism, the whole of space is filled with a Higgs field, and the way through which particles interact with this field, determines their specific masses. The Higgs boson is one of the new particles predicted by the Higgs mechanism.

[11] Our elaborations on data by Florio et al. (2016).

[12] The referendum-like approach is also known as single-bounded dichotomous choice approach.

question should be greater than that offered in the initial payment offer if the answer to the initial payment question is '*yes*', otherwise the follow-up procedure is stopped. Although this approach is statistically more efficient than the referendum approach, Alberini et al. (1997) found that the average WTP estimated after the follow−up approach can be lower than that implied by the responses to the initial payment question. A possible explanation is that some respondents may treat the suggested bid as a signal for the quality of the good and/or might erroneously believe that the program to be valued in the follow−up is different from the initial one. Furthermore, the follow−up procedure has been criticized because it does not mirror market mechanisms.[13] On the other side, single referendum elicitation format is vulnerable to anchoring effects (Green et al. 1998).

Drawing from the methodological insights of this literature, we carried out a CV survey to achieve two goals. First, to detect the explanatory variables potentially affecting individuals' WTP for the LHC. Second, to estimate the expected individual WTP for the LHC as a provider of scientific discovery in our sample. The questionnaire was designed to be consistent, as far as possible, with the guidelines by Arrow et al. (1993), while some modifications were applied to take into account the peculiarities of the good under evaluation. A pilot survey was conducted at the University of Milan in order to calibrate the structure, the number of questions and the duration of the interview as well as to verify the questionnaire was readable and clear so as to reduce the rate of rejection from respondents.[14]

A brief description of the LHC was provided to interviewees: a shortened version of the Wikipedia entry "Large Hadron Collider", including five photos. The questionnaire was structured along three sections. A first section investigated background knowledge and broad awareness of respondents about RIs. Open-ended and five-point Likert scale questions were added to binary-choice questions to further detect the interviewees' preferences and interest towards research. A second section focused on LHC and included questions to elicit the WTP (see below). A final section of the questionnaire asked personal information and, specifically, questions about socio-economic characteristics potentially affecting individual preferences. In particular, it inquired on age, sex, country of residence, university studies, income, and household composition.

The WTP was inquired in two ways. First, respondents were asked about their willingness to offer a single lump-sum payment amounting to EUR 30. They had three possible alternative answers: '*yes*', '*no*' and '*do not know*'. The amount of EUR 30 comes from Florio et al. (2016), who has carried out an analysis of CV studies worldwide on the existence value of public goods, particularly environmental, health and cultural goods. Second, the WTP was asked in the form of an annual fixed contribution for a period of 30 years. In particular, the bids of EUR 0, EUR 0.5, EUR 1 and EUR 2[15] per year were proposed, by stemming from the following facts. The 30 years' time-span suggested in our survey is the period that goes from the approval of the LHC project's budget in 1996 to the LHC planned decommissioning in 2025. The same time period was used in the CBA of the LHC by Florio et al. (2016).[16]

[13] Johansson suggested that if the first option is accepted, then it makes no sense to ask to pay more.

[14] The pilot test involved a total of 61 students. More details on the survey, the questionnaire and on the results are presented in Catalano et al. (2014). The questionnaire was originally submitted in Italian during the pilot test and then translated in English, French and Spanish.

[15] At a general public conference on the LHC at CERN in 2008, Dr. Fabiola Gianotti, General-Director of CERN since 2016, stated that CERN costs to the taxpayers 'a cup of coffee per year'(https://indico.cern.ch/event/416935/session/4/contribution/5/attachments/859149/1201296/esof2008.pdf). Since then, this citation has been repeatedly used by LHC stakeholders (http://vmsstreamer1.fnal.gov/Lectures/LectureSeries/presentations/110415Meddahi.pdf). Thus, the offered options were centered around the 'one cup of coffee per year' benchmark and respectively one half or twice that reference point. See section 4 for further details.

[16] Note that the EUR 30 lump-sum is also roughly equivalent to 'one cup of coffee over 30 years'.

Some CV studies test whether the mean WTP changes according to the manner the WTP question is asked, that is periodic payment versus lump-sum payment (see for example Echevveria et al. 1995, Green et al. 1998). In the present study, we are not interested, however, in comparing the expected WTP coming from the two ways of asking the CV question, instead we would like to know whether the determinants of WTP are different according to the way the WTP is asked and in this case to know what motivates such difference. Hence, we proposed respondents to fill in both the CV questions and in both cases they have been reminded that their willingness to pay for the LHC would reduce their budget for other goods.

Respondents were also asked to explain their choice by filling an open-ended question as a proof of his/her sincerity and to identify "protest bids"; i.e. investigate the reason why people are not willing to pay for the good (Dubgaard 1996). Loomis et al. (1996) and Hansen (1997) understand protest bids as a rejection of the CV study approach itself or as an expression of the political ideology of the respondent. If protest bids were identified, they will be sifted out from the analysis.

We chose to add a '*do not know'* option to '*yes*' and '*no*' options when asking about the lump-sum WTP. This structure seems particular convenient when people are willing to pay for something beneficial for the human-kind, as the fundamental research is supposed to be, but people do not know what precisely they should pay for. Thus, the benefit of offering a 'middle' response in addition to the referendum-like options '*yes*' and '*no*' is that uncertain survey respondents are not forced to construct a willingness to pay when answering a dichotomous choice question. The cost is a reduction in sample size and econometric efficiency if the '*do not know*' answers are dropped from the empirical analysis (Hansen 1997; Groothuis and Whitehead 2002).

Interviews were face-to-face, and required 20-30 minutes. Furthermore, respondents' strategic behavior was tackled by ensuring the anonymity of the questionnaire so as to reduce suspicions related to highly sensible information (Bohm 1972; Arrow et al. 1993).[17]

In what follows we present the econometric specifications and models. Data and descriptive statistics are presented in section 4.

Our first research question was to examine the explanatory variables affecting individuals' WTP. To this end, we adopted two approaches: a zero-inflated ordered logistic model was used when the dependent variable was the WTP expressed in the form of an annual fixed contribution while a standard multinomial logistic model was applied when the WTP was asked as a single lump-sum payment.

In the first case, the WTP is a discrete ordered variable, including the zero value. As demonstrated by Harris and Zhao (2007), traditional ordered logit models have limited capacity in explaining zero observations. This suggests using a zero-inflated ordered logit model by applying a double combination of a split logit model and an ordered logit model. Assume we observe N independent observations where the dependent variable of interest, WTP_i $(i = 0,1, \dots, N)$ is a count variable that displays a large proportion of zeros. Each individual belongs to one of two groups. The first group includes individuals who chose the zero option (they were not willing to pay), while the second group includes respondents for whom the WTP was positive. This suggests a two-stage approach. In the first stage we examine the binary decision to be willing to pay or not to pay. In the

[17] Strategic behaviour occurs when a systematic error is introduced into the sampling, when respondents select one answer over others in order to not to reveal their true opinion/position. A well-known case is that of perceived government-supported surveys leading people to skip highly-sensible information like income.

second stage, we investigate the probability of falling in one of the bid categories conditional on the decision to be willing to pay (Harris and Zhao 2007; Kasteridis et al. 2010).[18]

The binary decision to pay is modeled with a logit model. Let the underlying response variable p_i^* be defined by the latent regression:

$$p_i^* = X_{1i}\gamma + u_i \tag{1}$$

where the latent variable p_i^* measures the difference in utility derived by individual i from being willing to pay and not being so, X_1 is a vector of exogenous variables affecting individuals' preferences, γ is a vector containing all the parameters in the model and u is the error term. The observed binary variable for being willing to pay ($P_1 i$) relates to the latent variable ($p_1 i^{\dagger} *$) such that:

$$P_i = \begin{cases} 1 \; if \; p_i^* > 0 \\ 0 \; otherwise \end{cases} \tag{2}$$

From equation (1) and (2) the probability of paying is

$$\Pr(P_i = 1) = \Lambda(X_{1i}\gamma) \tag{3}$$

where $\Lambda(.)$ is the logistic cumulative distribution function (cdf) of u_i. The observed values of P_i are the realisations of a binomial variable with probabilities given by equation (3) conditional on X_{1i}. Thus the likelihood function is given by:

$$L(\gamma|P_i, X_{1i}) = \prod_{P_i=0} [[1 -] \Pr(P_i = 1)] \prod_{P_i=1} \Pr(P_i = 1) \tag{4}$$

Once modeled the decision to be willing to pay or not to pay, we focus on the level of the bid chosen. Let WTP_i be our dependent variable measuring the level of the proposed bids and takes on integer values from 0 to J. The variable WTP_i takes the value of zero for those respondents who chose the zero option $(P_i = 0)$. Nonzero values can only be observed conditional on $P_i = 1$. The joint likelihood of observing the entire sample is:

$$L(\theta|WTP_i) = \prod_{P_i=0} [[1 -] \Pr(P_i = 1)] \prod_{P_i=1} \Pr(P_i = 1) \Pr[(WTP_i | P_i = 1)] \tag{5}$$

where θ is a vector containing all the parameters in the model and the products are taken over sample observations satisfying $(P_i = 0)$ and $(P_i = 1)$. The conditional density $\Pr[(WTP_i | P_i = 1)]$ can be handled by an ordered logit model (Greene 2012; McKelvey and Zavoina 1975). In our

[18] In principle we may estimate an ordered choice model on the entire sample, including those individuals with zero WTP. As explained by Harris and Zhao (2007), this strategy could invalidate our results because the presence of many zeros in our response variable may indicate two distinct data generating processes and WTP behaviors. If so, a single latent equation model, as the ordered logit model, would not allow for the differentiation between these two aspects. Differently, we may estimate a truncated ordered choice model by throwing out zero observations incurring, in this case, in the sample selection problem (Greene 2012; Verbeek 2008). This trade-off leads us to implement a two-stage approach.

model each individual reveals the strength of her preferences with respect to the level of bid chosen. Although the preferences will probably vary continuously in the space of individual utility, the expression of those preferences is given in a discrete outcome on a scale with a limited number of choices. As a result, the model is constructed around a latent regression of the following form:

$$WTP_i^* = X_{2i}\beta + \varepsilon_i \tag{6}$$

where WTP_i^* can be interpreted as the propensity to be willing to pay at different bids, X_2 is a vector of exogenous variables aiming at explaining the level of bid and ε_i is the random disturbance term that follows a logistic distribution. The variable WTP_i relates to the latent variable ($\llbracket WTP \rrbracket_i^*$) according to the rule:

$$WTP_i = 1 \; if \; WTP_i^* \leq \tau_1$$
$$WTP_i = j \; if \; \tau_{j-1} < WTP_i^* \leq \tau_j \; j = 2, \dots, J-1$$
$$WTP_i = J \; if \; \tau_{J-1} < WTP_i^* < \infty$$

where $\tau_1 \leq \tau_2 \leq \dots \leq \tau_{J-1}$ are unknown thresholds (cut-points) to be estimated.

The conditional distribution of WTP_i given $P_i = 1$ and X_{2i} and the likelihood function of this sub-sample are given respectively by equations (7) and (8)

$$\Pr(WTP_i = j | P_i = 1) = \Lambda(\tau_j - X_{2i}\beta) - \Lambda(\tau_{j-1} - X_{2i}\beta) \tag{7}$$

$$L(. | WTP_i, X_{2i}) = \prod_{j=1}^{J} [\Lambda(\tau_j - X_{2i}\beta) - \Lambda(\tau_{j-1} - X_{2i}\beta)]^{WTP_{ij}} \tag{8}$$

where WTP_{ij} is an indicator variable equal to 1 if WTP_i falls in the j-th category and 0 otherwise.

Ideally, we should estimate the model presented in equation (5). From a statistical perspective, it describes the joint distribution of the random variables WTP_i and P_i conditional on the explanatory variables contained in X_{1i} and X_{2i} with the variance-covariance structure of the bivariate distribution of the error term $\xi \equiv [u_1 i \;\; \varepsilon_1 i]'$ defined by the following matrix:

$$V(\xi) = \begin{bmatrix} \sigma_\varepsilon^2 & \sigma_{\varepsilon u} \\ \sigma_{\varepsilon u} & \sigma_u^2 \end{bmatrix} \tag{9}$$

In this model, X_{1i} includes the variables that determine the decision process to be willing to pay or not to pay (the participation equation, 3) and X_{2i} those that influence the level of the bid chosen (the level equation, 7). In general, X_{1i} is an informative set contained in X_{2i}. Unfortunately, our dataset does not allow us to provide variables that would affect the participation equation but not the level equation or vice versa, so we have that $X_{1i} = X_{2i}$. Being so, we impose the covariance between u_i and ε_i to be zero. This allows us to estimate equation (3) and equation (7) separately;

specifically we are going to estimate the equation (3) by using the whole sample and the equation (7) by using an ordered logit model over the sub-sample in which we observe $P_i = 1$.[19]

The determinants of WTP when expressed in the form of a single lump-sum payment are investigated by estimating a standard multinomial (MNL) logit model (Maddala 1994, for details Greene 2012).

The reference model to estimate the existence value of environmental and cultural goods is the utility difference model developed by Hanemann (1984). We use this model to provide an answer to our second research question, which is the average contribution that the respondents would be willing to pay for LHC. Let's assume that the dependent variable of interest, S_i $(i = 0,1)$ is a binary variable. S_i = 0 identifies individuals who would not be willing to pay for the good being evaluated; in contrast, S_i = 1 identifies people willing to pay the bid proposed by the interviewer. Each individual has an indirect utility function of the form $V(M;\, Y_i;\, Z_i)$ where Y_i is income, Z_i is vector of exogenous variables affecting individuals' preferences (in our case socio-economic characteristics and attitude towards research) and M is a binary variable describing the state of the world with or without the good under evaluation.

When interviewed, the respondent has two options: (a) to answer '*no*' and face the state of the world in absence of the good $(M = 0)$ and keep all of his/her income $(Y_1 i)$; (b) to choose '*yes*' and thus having his/her income reduced by the bid (A) but the good available for the future $(M = 1)$. An individual will respond '*yes*' if and only if his/her utility under option (b) is greater than or equal to that under option (a): $\delta V_i^* = V(1; Y_i - A;\, Z_i) - V(0; Y_i;\, Z_i) + v_i \geq 0$.

Empirically, the probability that the individual accepts the offer (A) is approximated with a binomial model given by

$$\Pr(S_i = 1) = \Lambda(\delta V_i^*) = \Lambda\,(\alpha + A\beta_1 + Y_i\beta_2 + Z_i\beta_3) \qquad (10)$$

where the latent variable δV_i^* measures the difference in utility, $\Lambda(.)$ is the logistic cdf of the error term v and α, β_1 , β_2 , β_3 are the parameters of the model to be estimated, where $\beta_1 \leq 0$ and $\beta_2 > 0$ are expected.

Once equation (10) is estimated, the expected value of WTP is obtained by numerical integration. As argued by Duffield and Patterson (1991) there are three methods to compute the value of WTP. The first is to compute the WTP by integrating equation (10) from $-\infty$ to $+\infty$ obtaining the so called overall mean WTP. Since the WTP is nonnegative, this method is not appropriate. Thus the two alternative approaches are to compute the expected value of the WTP integrating from 0 to $+\infty$ or the truncated mean WTP integrating from 0 to maximum bid (A) . The authors suggest that the truncated mean WTP is the most appropriate method because satisfies theoretical constraints (the upper limit of the WTP is not infinity but something less than income), is statistical efficient in the sense that reduces the influence of the upper tail of the empirical distribution of WTP and satisfies the aggregation criteria. By using this method the value of the maximum bid (A) has to be assigned to all recorded WTP above (A) . Thus:

[19] This is a limitation of the study. However, several papers in different fields use this approach. See for example Geda et al. (2001), Lera-Lopez and Rapun-Garate (2007), Kasteridis et al. (2010).

$$E(WTP) = \int_0^{MAX\ A} \Lambda\left(\delta V_i^*(A)\right)\delta A =$$

where $\hat{\alpha}^*$ is the estimated adjusted intercept wich was added by the socio-economic characteristics and reasearch-attitude factors to the original constant $\hat{\alpha}$.

In what follows, the truncated mean WTP is obtained by making use only for the lump-sum payment of EUR 30.

4 Data and descriptive statistics

The CV survey was conducted between June 2014 and March 2015. 1022 valid questionnaires were filled in by students coming from five European universities located in four countries: University of Milan (Italy), University of Exeter (UK), University Paris 7- Denis Diderot and Sciences Po University (France), University of A Coruña (Spain).

The descriptive statistics of the variables related to the profile of students in terms of social features and respective codes are presented in Table 1. The sample comprises 420 (41%) students from Italy, and about 200 (20%) from Spain, France and the UK each. They are enrolled in more than 30 different university degrees with an overall balance between three main fields of education: 398 (39%) of respondents are enrolled in humanistic related curricula[20], 257 (25%) in social sciences[21] and 352 (34%) in scientific degrees.[22] 578 (57%) respondents are female and 86% (857 students) is aged between 19 and 25 years, while the remaining share is more than 26 years old. Most of students belong to a family from 3 to 5 members (774 corresponding to 75.7% of the sample), 174 (17%) to a family with 1 or 2 members and only a tiny share (7.2%) to a family with more than 5 people.

Table 1 Descriptive statistics of social characteristics

Variable	Code	Number	Per cent
C0.1 Country	1= Italy	420	41.1
	2= Spain	202	19.8
	3= France	200	19.6
	4= UK	200	19.6
C0.2 Education [a]	1= Humanities	398	38.9
	2= Social sciences	257	25.1
	3= Scientific	352	34.4

[20] These include law, foreign languages, international relations, literature, philosophy, history, geography, cultural assets, communication and media, theology, cryptography, musicology.

[21] Including economics, finance, marketing and management, political sciences, sociology, semiology, anthropology, humanitarian sciences, sport sciences, urban studies, education.

[22] Such as medicine, pharmacy, chemistry biology, mathematics, physics, engineering, architecture, mechanics, ICT.

C1 Age	1= 19-25	875	85.6
	2= 26-30	94	9.2
	3= 31-35	33	3.2
	4= > 35	20	2.0
C2 Gender	0=Male	444	43.4
	1= Female	578	56.6
C8 Household Composition	1= 1-2	174	17.0
	2= 3-5	774	75.7
	3= > 5	74	7.2

Question C0.1: Country of residence.
Question C0.2: Faculty.
Question C1: Age
Question C2: Sex
Question C8: Household composition (including parents, brothers/sisters).
[a] 15 observations are missing

Regarding income, respondents were inquired both on the availability of a personal income and on the amount of the family income. The joint distribution of income variables is reported in Table 2. Numbers in parentheses denote the distribution function of the single variable. Only 304 (30%) students earn an own income. The largest share (70%) is financially supported by his/her family. Most of households fall in the income category ranging from EUR 1,000 to 3,000 per month (478 respondents, representing 47% of the sample), followed by a 23% share with monthly income ranging from EUR 3,000 to 5,000. 19% and 11% of respondents fall in the lowest (less than EUR 1,000) and highest (more than EUR 5,000) family-income categories respectively. The Spearman's correlation coefficient between the two variables is negative meaning that students who earn an own income come from families with a low-medium income. Table 2 shows that 65.2% of respondents with a personal income belong to families with less than EUR 3,000 per month. In the following analysis, it was decided to use the family income (Question C6) as independent variable rather than the availability of own income (Question C7). This approach is based on the fact that only 30% of respondents earn their own income; therefore it is very likely that their decision-making process about WTP is highly influenced by the family budget constraints.

Table 2 Descriptive statistics of income variables

		C7 Respondent's availability income	
		0=No	1=Yes
C6 Family monthly income (EUR) [a]		718 (70.3%)	304 (29.7%)
1= < 1,000	189 (18.5%)	15.9%	25.4%
2= 1,000 - 3,000	478 (46.8%)	50.3%	39.8%
3= 3,000 - 5,000	231 (22.6%)	23.1%	22.4%
4= > 5,000	113 (11.1%)	10.7%	12.4%

Question C6: In which of the following brackets does your family monthly net income fall?
Question C7: Do you have your own personal income?
[a] 11 observations are missing

Previous knowledge and awareness of respondents about RIs as well as their attitude towards scientific discoveries are presented in Table 3. Out of 1022 respondents, 554 (54.2%) are aware of what a research infrastructure is and 480, representing the 53% of the whole sample, associate it with a particle accelerator when asked to identify a RI amongst some alternatives (see Question A2, Table 3). 845 (83%) interviewees stated that they have an interest for scientific discoveries, and more in general for scientific research, and 85% recognizes that funding RIs is at least important. The LHC is known by 535 (52.3%) interviewees. Their source of information includes mainly internet, magazines and TV (62.4%). 117 (21.9%) students declared that they have heard about LHC at university or cultural activities such as seminars and meetings while 83 (15.7%) by friends. Higgs Boson is known by 620 (60.7%) respondents and 97 (9.3%) had already visited CERN.

Table 3 Interest in research and knowledge of LHC

Variable	Code	Number	Per cent
A1 Knowing what a RI is	0= No	468	45.8
	1= Yes	554	54.2
A2 Particle accelerator	1= Particle accelerator	480	53.0
	0= Other	542	47.0
A4 Interest in research	0= No	177	17.3
	1= Yes	845	82.7
A6 Importance of funding RI	1= Useless	4	0.4
	2= Insignificant	13	1.3
	3= Important Enough	142	13.9
	4= Important	473	46.3
	5= Fundamental	390	38.2
B1 Having heard about LHC	0= No	487	47.7
	1= Yes	535	52.3
B2 Source of information about LHC	University	117	21.9
	TV	119	22.3
	Magazines	86	16.1
	Internet	130	24.0
	Friends	83	15.7
B3 Having heard about Higgs Boson	0= No	402	39.3
	1= Yes	620	60.7
B5 Having visited the CERN	0= No	927	90.7
	1= Yes	97	9.3

Question A1: Do you know what a research infrastructure is?
Question A2: In your opinion, which of the following is a research infrastructure? telescope; instrument of data collection and archive; data elaboration software; particle accelerator; library; computer; astronomical observatory; planetarium.
Question A4: Are you interested in scientific discoveries and in research activities in general?
Question A6: how do you rate the importance of funding research infrastructures?
Question B1: Did you hear about the LHC before this questionnaire?
Question B2: If yes, please indicate your source of information.
Question B3: Did you ever hear of "Higgs Boson"?
Question B5: Have you ever been to the CERN?
[a] Elaborations on B1=Yes

Table 4 presents the descriptive statistics and the joint distributions of the questions related to WTP. Again, numbers in parentheses denote the distribution function of the single variable. Respondents stated their willingness to pay for the LHC in the following way. First, a general question was submitted to detect the students' willingness to pay for the research activity at the LHC, without mentioning any bid (Question B8). 496 (48%) respondents declared that they do not know whether they are willing or not to contribute to the activity of LHC, 335 (33%) explicitly declared they would not be willing to financially support the LHC, while 191 (19%) respondents were willing to financially support the LHC (Table 4, Panel A)

Afterwards, two questions integrating, respectively, two different payment systems, were submitted. The first question (B10) was: "*By 2015, would you be willing to offer an economic contribution equals to EUR 30 turning down other personal expenses*?" with the offered answers being '*yes*', '*no*' and '*do not know'*. The second question (B12) was: "*If someone asks you to give an economic contribution to the LHC by means of an annual tax over a period of 30 years, would you be willing to pay an annual amount equal to: EUR 0, EUR 0.5, EUR 1 and EUR 2*". The survey reveals that 147 interviewees (14%) are willing to pay EUR 30 una tantum, 500 (49%) would not pay as much, and 375 (37%) would not know (Table 4, Panel A).

When looking at the second question, the share of respondents who would be willing to contribute EUR 0.5, EUR 1 and EUR 2 are respectively 83 (8%), 229 (22%) and 438 (43%). The remaining 27% (274 students) would be willing to pay EUR 0 (Table 4, Panel B).

Table 4 Descriptive statistics of the WTP questions

PANEL A	(B10) By 2015, would you be willing to offer an economic contribution equal to 30 euros (lump sum) turning down other personal expenses?			
(B8) Would you be willing to provide an economic contribution to fund the research activity of LHC?	No	Yes	I do not know	Total
No	287	3	45	335 (33%)
Yes	54	89	48	191 (19%)
I do not know	159	55	282	496 (48%)
Total	500 (49%)	147 (14%)	375 (37%)	1,022 (100%)

PANEL B	(B12) If someone asks you to give an economic contribution to the LHC by means of an annual tax over a period of 30 years, would you be willing to pay an annual amount equal to:				
	EUR 0	EUR 0.5	EUR 1	EUR 2	Total
No	179	28	48	80	335
Yes	6	6	47	132	191
I do not know	87	49	134	226	496
Total	274 (27%)	83 (8%)	229 (22%)	438 (43%)	1,022 (100%)

In both WTP scenarios, five protest bids were identified. Three respondents said '*no*' in the lump-sum scenario and chose EUR 0 in annual payment scenario because they think national governments should be in charge of funding RIs; while two respondents were against the allocation of resources for the LHC in time of crisis. Protest bids represent a negligible share (2%) and they have no effects on our findings. The most quoted motivations behind not to be willing to pay were the non-affordability of the bid offered, the low interest in scientific discoveries and the lack of sufficient information about LHC.

Table 4 reveals some interesting facts. Firstly, it is worth noting that the share of respondents who would be willing to contribute at least EUR 0.5 to the LHC via an annual tax is much higher (73%) than that declared in the lump sum question (14%). Among this 73%, about 60% would be willing to pay an annual contribution of EUR 2 that is the highest offered option. These figures confirm that people react differently to different payment proposals in line with many CV studies (Echevveria et al. 1995; Green et al. 1998). In the next section, we investigate in depth the individuals' characteristics affecting such making decision process.

Secondly, Table 4 suggests an empirical strategy to estimate the expected WTP for the LHC. In order to apply the Hanemann's model, we exploit the variation in the data coming from the joint distribution of the questions B8 and B10. Specifically, our strategy consists of identifying those respondents whose maximum WTP is EUR 30 or even more. Panel A shows that there are 500 students who answered '*no*' to the question (B10) and 48 respondents with answers of '*yes-do not know*' type. For these students, it is very likely that their WTP falls between EUR 0 and an (unknown) amount smaller than EUR 30. In contrast, the group of students (147) who answered '*yes*' to the question (B10) are willing to pay at least EUR 30. At this point, we construct a dummy variable (BID) that takes on the value 1 for these respondents and 0 otherwise. By applying this strategy, we also decided to exclude 282 answers with the '*do not know-do not know*' combination away and estimate the expected WTP by using a restricted sample with only '*yes*' and '*no*' records. This choice allows us to elicit only the stronger opinions on the issues; the cost is the loss of efficiency in the econometric analysis (Groothius and Whitehead 2002), but also we reduce the role of interpretation of the answers. Indeed, these restrictions reduce our sample from 1,022 to 740 individuals.

Table 5 analyses the overall correlation between the variables presented above. As the variables are expressed in ordinal intervals, we use the Spearman's rank correlation matrix. It should be noted that the variables related to the LHC, the Higgs boson and the CERN (B1, B3 and B5) are strongly correlated each other. Hence, to avoid significant multicollinearity we leave the variable B5 out in the econometric exercise.[23]

5 Results

We start with examining the determinants of individuals' WTP when expressed in the form of an annual fixed contribution for a period of 30 years with four options: EUR 0, EUR 0.5, EUR 1 and EUR 2. ML estimates of equation (3) and the marginal effects of each variable are presented in Table 6. In order to estimate the binomial logit model, we convert the dependent variable in a binary variable, which takes the value of 1 for they would be willing to pay and 0 otherwise. Therefore the model explains the probability of observing a positive WTP.

In column (1), we examine the impact of the socio-economic features leaving out the variables expressing attitude and interest towards research. The latter were added in column (3). In both cases we control for country-specific effects to capture unobserved country heterogeneity. The latter are particularly relevant within this study because the WTP of the respondents may depend on the extent to which a country contributed to the funding of the LHC or on the country's exposure to the

[23] The Spearman's correlation coefficients between the variable "B5 Having visited CERN" and "B1 Having heard about LHC" and "B3 Having heard about Higgs boson" are 0.50 and 0.7 respectively.

CERN.[24] Average marginal effects of the two specifications are reported in columns (2) and (4) respectively.

[24] For example, Italy is the most represented country at the CERN with more than 700 scientists. Moreover at the end of 2014, the Italian physicist Fabiola Gianotti was elected General-Director of the CERN and her mandate began on 1 January 2016.

Table 5 Spearman's Rank Correlations

	B10	B12	BID	C0	C1	C2	C6	C8	A1	A2	A4	A6	B1	B3	B5	
B10 WTP Fixed contribution	1															
B12 WTP Annual payment	0.26**	1														
BID	-0.55*	-0.09*	1													
C0 Education	-0.01	0.11**	-0.04	1												
C1 Age		-0.03	-0.10**	-0.05	-0.01	1										
C2 Gender	0.05	0.01	-0.02	-0.02	-0.05	1										
C6 Family monthly income	0.09**	0.02	0.02	-0.06**	-0.02	-0.05	1									
C8 Household composition	0.03	0.01	0.02	0.05	-0.01	0.03	0.07**	1								
A1 Knowing what a RI is		0.03	0.06	0.05	-0.12**	-0.06**	0.10**	0.01	0.04	1						
A2 Particle accelerator	0.03	0.07**	0.05	0.14**	0.05	-0.18**	-0.04	0.01	0.37**	1						
A4 Interest in research	0.10**	0.05	0.10*	0.13**	0.10**	-0.02	0.04	-0.05	0.07**	0.06**	1					
A6 Importance of funding RI	0.02**	0.15**	0.03	0.06	0.03	0.00	0.01	-0.08**	0.15**	0.13**	0.46**	1				
B1 Having heard about LHC	0.02	0.17**	0.03	0.15**	0.02	-0.20**	0.07**	-0.00	0.08**	0.26**	0.10**	0.16**	1			
B3 Having heard about Higgs Boson	0.05	0.15**	0.05*	0.11**	0.00	-0.20**	0.07**	0.01	0.01	0.10**	0.27**	0.17**	0.14**	0.47**	1	
B5 Having visited the CERN	0.02	0.07**	0.01	0.06**	0.00	-0.02	0.02	0.01	-0.00	0.04	0.04	0.10**	0.05	0.50**	0.66**	1

** Significant at 5% level.

Table 6 Determinants of WTP. Binomial logit estimates

	(1)		(2)		(3)		(4)	
Variables	coef	se	dy/dx	se	coef	se	dx/dy	se
Family income								
1,000-3,000	0.438**	(0 .207)	0.081**	(0.039)	0.425**	(0.211)	0.076**	(0.039)
3,000-5,000	0.552**	(0.233)	0.100***	(0.042)	0.556**	(0.239)	0.098**	(0.042)
> 5,000	0.469*	(0.292)	0.086*	(0.052)	0.391	(0.304)	0.071	(0.054)
Female	-0.001	(0.153)	-0.000	(0.026)	0.167	(0.160)	0.028	(0.027)
Age								
26-30	-0.143	(0.254)	-0.025	(0.046)	-0.199	(0.263)	-0.034	(0.047)
31-35	-0.848**	(0.353)	-0.167**	(0.075)	-0.884**	(0.350)	-0.169**	(0.073)
> 35	-0.864*	(0.483)	-0.170*	(0.103)	-1.033**	(0.510)	-0.200*	(0.108)
Education								
Humanities	0.188	(0.174)	0.032	(0.030)	0.256	(0.182)	0.029	(0.030)
Social Science	0.123	(0.202)	0.021	(0.034)	0.224	(0.209)	0.037	(0.034)
Household composition								
3-5	0.315	(0.185)	0.057	(0.040)	0.343	(0.226)	0.060	(0.041)
> 5	-0.109	(0.302)	-0.021	(0.058)	-0.013	(0.309)	-0.002	(0.058)
A1 Knowing what a RI is					-0.085	(0.178)	-0.014	(0.030)
A2 Particle accelerator					0.304*	(0.170)	0.051*	(0.029)
A4 Interest in research					0.096	(0.206)	0.016	(0.036)
A6 Importance of funding RI					0.185*	(0.110)	0.035*	(0.020)
B1 Having heard about LHC					0.305*	(0.177)	0.052*	(0.031)
B3 Having heard about H. Boson					0.354**	(0.185)	0.063**	(0.032)
Constant	1.118***	(0.312)			-0.253	(0.617)		
Country-specific effects	yes				yes			
Observations	1,010		1,010		1,009		1,009	
% Correct predictions	75.0				76.0			
McFadden's R2	0.0362				0.117			
Log Likelihood	-565.2				-517.8			
Likelihood ratio test	40.80				126.1			

Income enters positively and significantly into both models. For example, belonging to a family with monthly income between EUR 3,000 and 5,000 increases the probability of declaring a positive WTP by about 10 percentage points compared to a student belonging to a family with an income less than EUR 1,000 ceteris paribus (Columns 2 and 4).

The coefficients on age variables are statistically significant at either the 10% level or 5% level with negative sign. The negative sign indicates that the probability of WTP '*yes*' is likely to be higher in younger students than in older one.[25]

Most of CV studies show that, on average and depending on the good under evaluation, a more educated population is more likely to be willing to pay for public goods (Whitehead and Blomquist 1991; Echeverria et al. 1995; Thompson et al. 2002; Amirnejad et al. 2006). Florio et al. (2016) argue that more educated people would probably be willing to pay more for the LHC than less educated people. The lack of significance of education in the participation equation, can be easily explained by noting that our survey did not target people with different educational attainments, but university students enrolled in several curricula; so the variation in education across respondents is not in terms of years spent in education but exclusively in terms of background and subject preferences, see below. Amongst the source of information about the LHC, on-line news and TV programs are the most quoted by the interviewees. Being so, is not an anomaly to observe no differences in the probability of observing a positive WTP across university degrees.

Finally, no significant gender and family composition differences exist on the WTP; in contrast knowing what is a particle accelerator, having heard about the LHC and the Higgs Boson and declaring that the fundamental research is important to some extent, increase the probability of a '*yes*' response.[26]

Table 7 presents the estimates of the ordered logit model conditional on the sub-sample of students who are willing to pay (Equation 7). Also reported in the table, there are the marginal effects of explanatory variables in model 2 for each category of WTP.

Column 2 shows that in this context the higher the income, the less likely is the probability of choosing EUR 2. Economic theory, structure of the question and/or the data themselves can help us to explain this result. Economists agree that giving or donating behavior as a function of income is not linear, but has a U-shaped pattern-people in the lowest and highest income groups and this relationship persists even when accounting for additional variables associated with income (McClelland and Brooks, 2004).

University degrees such as humanities and social sciences display negative coefficients with respect to scientific degrees. In the case of the highest category of WTP (column j= € 2), being enrolled in social science faculties reduces the probability of donating EUR 2 by 13 percentage points compared to students enrolled in scientific degrees such as mathematics or physics. Hence, although the variable education does not affect the participation equation (to pay or not to pay), it matters in determining the level of WTP. As expected, importance of funding RI and having heard about LHC are associated with higher levels of WTP.

Finally, the taos (τ) parameters refer to the thresholds used to differentiate the adjacent levels of the dependent variable. They are all statistically significant, justifying the use of three categories of

[25] The negative sign remains even when we use the availability of a personal income (unreported regression) rather than the family income confirming an inverse relationship between age and WTP, once income has been netted out.

[26] The non-significance of the variables "A1 Knowing what is a RI" and "A4 Interest in research" is due to the collinearity with "A2 Particle accelerator" and "A6 Importance in research" respectively. The Spearman's correlation coefficients are respectively 0.4 and 0.5 (see Table 5)

the level of WTP over combining some categories. Moreover, the likelihood ratio tests in the models indicate that the variation in the independent variables explains a good proportion of the variability in the response variable.

The determinants of WTP when expressed in the form of a single lump-sum payment amounting to EUR 30 are investigated by estimating a standard multinomial (MNL) logit model. Estimation of a MNL model will enable us both to allow for and to test for differences in the factors associated with each of the three outcomes: '*yes*', '*no*' and '*do not know*'. Tests were also conducted to determine whether the assumption of Independence of Irrelevant Alternatives (IIA), underlying the MNL specification, holds.[27]

Multinomial logit estimates are reported in Table 8. As before, model 1 leaves out variables expressing attitude of students towards research; these factors were added in the model 2. Table 8 reveals that the higher the income, the higher the probability of being willing to pay EUR 30 with respect to not be willing to pay (the base case), that is to say '*yes*' with respect to say '*no*' (Column 3). The effect of income is mitigated for students who answered '*do not know*' with respect to those who answered '*no*' (Column 4). Differently from income, the demographic characteristics (gender, age, education and household composition) are not significant determinants of WTP outcome.

The variable "A2 Particle accelerator" is positively associated with the WTP, i.e. respondents who identify a RI with a particle accelerator are more likely to answer '*yes*' than '*no*', as compared to respondents who did not recognize the LHC as a RI (Column 3). Moreover, this variable discriminates also '*do not know*' answers compared to '*no*' ones (Column 4).

In line with expectations, having some interest in research activities, judging funding research infrastructures important and having heard about LHC have jointly a positive and statistically significant impact on answering '*yes*' relative to '*no*'.

Summing up, our empirical analysis show that income and variables expressing interest and attitude towards research are positively associated with a '*yes*' response; in contrast and conditional to our sample, the type of university degree does not discriminate between paying and not paying. The type of education matters, however, in the WTP level equation: students enrolled in scientific degrees such as mathematics, physics, engineering and medicine are willing to pay more for science. In contrast to the expectations, income shows a negative sign in the level equation, a result probably due to the fact that most respondents do not earn income on their own or to the lack of enough variation in the data.

We turn then to determining a truncated mean WTP. Results of the logit model (11) are presented in Table 9. As expected, the estimated coefficient on BID was found negative and statistically significant. Family income significantly impacts on the probability of WTP '*yes*' and the sign was positive. The effect of other variables was discussed in the previous sections. The Count R^2 reveals that 75.5% of observations were correctly allocated to predict WTP either '*yes*' or '*no*', indicating a good fit to the data.

[27] According to the assumption of Independence of Irrelevant Alternatives (IIA), residuals must be independent each other, with a log-Weibull distribution. If two alternatives are more similar to one another than the third alternative, as might be supposed, for example, if individuals answering '*do not know*' and '*no*' behave similarly (Groothuis and Whitehead, 2002), we would expect the test of IIA to reveal such similarities. In order to test the IIA assumption, we conducted two Hausman tests. In the first one, the MNL results were compared with those from a binomial logit model between the '*no*' and '*yes*' samples. In the second one, the MNL results were compared with those from a binomial logit between the '*do not know*' and '*yes*' samples. The p-values associated with the resulting test statistics were 0.78 and 0.81 respectively, allowing us to fail to reject the IIA assumption and provide further credibility to the use of a MNL procedure.

Table 7 Determinants of WTP. Ordered Logit Estimates: Models and Average Marginal Effects

	Model				Marginal Effects on Predicted Probabilities. Model 2					
	(1)		(2)							
VARIABLES	coef	se	coef	se	j= € 0.5	se	j= € 1	se	j= € 2	se
Family income										
1,000-3,000	-0.43*	(0.25)	-0.44*	(0.25)	0.03*	(0.02)	0.06*	(0.03)	-0.09*	(0.05)
3,000-5,000	-0.70***	(0.25)	-0.73***	(0.26)	0.06***	(0.02)	0.09***	(0.03)	-0.16***	(0.05)
> 5,000	-0.73**	(0.33)	-0.83**	(0.33)	0.07**	(0.03)	0.11***	(0.04)	-0.18**	(0.07)
Female	-0.29*	(0.15)	-0.19	(0.16)	0.02	(0.01)	0.02	(0.02)	-0.04	(0.03)
Age										
26-30	0.04	(0.24)	0.02	(0.24)	-0.00	(0.02)	-0.00	(0.03)	0.01	(0.05)
31-35	0.66	(0.55)	0.63	(0.59)	-0.05	(0.04)	-0.08	(0.07)	0.13	(0.11)
> 35	0.43	(0.77)	0.21	(0.78)	-0.02	(0.06)	-0.03	(0.10)	0.05	(0.16)
Education										
Humanities	-0.31*	(0.18)	-0.15	(0.19)	0.01	(0.02)	0.02	(0.02)	-0.03	(0.04)
Social Science	-0.67***	(0.21)	-0.59***	(0.21)	0.06**	(0.02)	0.07***	(0.02)	-0.13***	(0.05)
Household composition										
3-5	-0.06	(0.23)	-0.11	(0.24)	0.01	(0.02)	0.01	(0.03)	-0.02	(0.05)
> 5	-0.36	(0.38)	-0.28	(0.40)	0.03	(0.04)	0.03	(0.05)	-0.06	(0.09)
A1 Knowing what a RI is			0.22	(0.17)	-0.02	(0.02)	-0.03	(0.02)	0.05	(0.04)
A2 Particle accelerator			0.20	(0.17)	-0.02	(0.02)	-0.03	(0.02)	0.04	(0.04)
A4 Interest in research			0.09	(0.22)	-0.01	(0.02)	-0.01	(0.03)	0.02	(0.05)
A6 Importance of funding RI			0.61***	(0.12)	-0.06***	(0.01)	-0.08***	(0.01)	0.13***	(0.02)
B1 Having heard about LHC			0.35**	(0.18)	-0.03**	(0.02)	-0.05*	(0.02)	0.08**	(0.04)
B3 Having heard about H. Boson			0.22	(0.18)	-0.02	(0.02)	-0.03	(0.02)	0.05	(0.04)
τ_1	-3.18***	(0.37)	1.20*	(0.64)						
τ_2	-1.40***	(0.34)	1.91***	(0.65)						
Country –specific effects	yes		yes							
Observations	740		740		740		740		740	
McFadden's R2	0.0229		0.0618							
Log Likelihood	-661.2		-634.3							
Likelihood ratio test	28.24		73.38							

Table shows the determinants of the probability of falling in one of the WTP category. Robust standard errors in parentheses. ***,**,* denote significance at the 1%, 5% 10% level respectively.

Table 8 Determinants of WTP. Multinomial logit estimates. Base outcome *'no'*

	Model 1				Model 2			
	(1)		(2)		(3)		(4)	
	Yes		I do not know		Yes		I don not know	
VARIABLES	Coef	se	coef	se	coef	se	coef	se
Family income								
1,000 - 3,000	0.56*	(0.30)	0.34	(0.22)	0.49*	(0.30)	0.18	(0.22)
3,000 – 5,000	0.63**	(0.32)	0.45**	(0.23)	0.59*	(0.34)	0.34	(0.24)
> 5,000	1.20***	(0.39)	1.02***	(0.30)	1.01**	(0.41)	1.01***	(0.30)
Female	-0.11	(0.21)	0.04	(0.16)	0.15	(0.22)	0.05	(0.16)
Age								
26-30	0.904***	(0.33)	0.34	(0.26)	0.84**	(0.34)	0.29	(0.26)
31-35	-0.56	(0.67)	0.02	(0.39)	-0.25	(0.65)	-0.08	(0.40)
> 35	-0.16	(0.59)	-1.24	(0.68)	-0.06	(0.60)	-1.26*	(0.68)
Education								
Humanities	-0.13	(0.24)	0.03	(0.17)	0.17	(0.25)	0.11	(0.18)
Social Science	-0.19	(0.25)	-0.27	(0.20)	-0.03	(0.26)	-0.24	(0.20)
Household composition								
3-5	-0.43	(0.33)	-0.31	(0.24)	-0.55	(0.34)	-0.34	(0.25)
> 5	-0.51	(0.47)	-0.26	(0.33)	-0.30	(0.49)	-0.25	(0.33)
A1 Knowing what a RI is					-0.29	(0.23)	-0.09	(0.17)
A2 Particle accelerator					0.66***	(0.23)	0.40***	(0.17)
A4 Interest in research					0.55*	(0.33)	0.47**	(0.21)
A6 Importance of funding RI					0.49***	(0.18)	0.05	(0.10)
B1 Having heard about LHC					0.43*	(0.24)	-0.18	(0.18)
B3 Having heard about Higgs Boson					0.25	(0.26)	0.10	(0.25)
Constant	-0.02	(0.50)	0.17	(0.34)	-3.28***	(1.04)	-0.41	(0.55)
Country-specific effects	Yes		yes		yes		yes	
Observations	1,010		1,010		1,009		1,009	
% Correct predictions	50.2				52.1			
McFadden's R2	0.089				0.114			
Log Likelihood	-914.1				-889.0			
Likelihood ratio test	179.3				228.2			

Robust standard errors in parenthesis. ***,**,* denote significance at the 1%, 5% 10% level respectively.

Once the parameters of the logit model are estimated, the truncated mean WTP is given by

$$E(WTP) = \int_0^{30} [1 + \exp(-(3.66 - 0.481A))]^{-1}\, \delta A = € 7.7 \qquad (12)$$

The estimated mean WTP for basic research at the LHC is EUR 7.7 per person. By applying our estimation to the adult population of CERN member states, which amounted to 481 million people in 2013[28], it would suggest a non-use social benefit of EUR 3.7 billion (USD 4.1 billion). By adding to this population an additional 21%[29] to take into account the population of CERN non-member states that directly or indirectly support the LHC (e.g. notably the USA), the target population increases to 610.5 million, and the non-use benefit rises to EUR 4.7 billion (USD 5.1 billion). These figures are in the same range of the estimated non-use value provided by Florio et al. (2016) who use alternative approaches to CV and, within their framework, contributes substantially to achieve a positive social net present value of the LHC to 2025. This suggests that ignoring the non-use value

[28] Our elaborations on Florio et al. (2016) data. The authors estimate that the target population amounts to 481 million people aged between 18 and 80 in the following member states: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom, and Israel.

[29] The percentage of 21% represents the share of onsite visitors to CERN from non-member states. For further details see Florio et al. (2016). A large number of US scientists are involved in the experiments at LHC.

in cost benefit analysis of research infrastructures would lead to a severe underestimation of their overall socio-economic impact.

Table 9 Estimation of WTP. Results of logit models

VARIABLES	(1) Coef	se	(2) dy/dx	se
BID	-0.481*	(0.282)	-0.081*	(0.047)
Family Income	0.174*	(0.102)	0.029*	(0.017)
Female	0.020	(0.204)	0.003	(0.034)
Age				
26-30	1.258***	(0.321)	0.227***	(0.058)
31-35	-1.079**	(0.567)	-0.159**	(0.069)
>35	-0.738	(0.590)	-0.114	(0.082)
Household composition	0.031	(0.224)	0.005	(0.038)
Education	-0.065	(0.112)	-0.010	(0.019)
A2 Particle Accelerator	0.667***	(0.202)	0.114***	(0.034)
A6 Importance of funding RI				
Important enough	0.843	(0.736)	0.133	(0.106)
Important	1.306*	(0.693)	0.220*	(0.127)
Fundamental	1.657***	(0.691)	0.315***	(0.124)
B1 Having heard about LHC	0.366*	(0.206)	0.062*	(0.033)
B3 Having heard about Higgs Boson	0.436*	(0.235)	0.073*	(0.039)
Constant	-0.892	(0.929)		
Country-specific effects	Yes			
Observations	740			
Count R2	75.5			
McFadden's R2	0.208			
Log Likelihood	-364.8			
Likelihood ratio test	191.29			

Robust standard errors in parenthesis. ***,**,* denote significance at the 1%, 5% 10% level respectively. (*) dy/dx is for discrete change of dummy variable from 0 to 1.

6 Concluding remarks

Big Science has been considered the contemporary cultural equivalent of building pyramids or cathedrals, because of its high symbolic value. In the words of Weinberg (1961, p. 161): “History… will find in the monuments of Big Science – the huge rockets, the high-energy accelerators, the high-flux research reactors – symbols of our time just as surely as she finds in Notre Dame a symbol of the Middle Ages”.

As cathedrals, large-scale research infrastructures are costly, and governments are often asking to what extent they should fund them, particularly in the domain of basic science. We contribute to the literature on CBA of public goods by an assessment of the non-use value of the discovery potential at the LHC, as an example of a highly visible RI that generates knowledge not yet associated to any predictable application. We empirically show by a relatively large survey of students of four countries that there is a willingness to pay for basic research, even when respondents are enrolled in non-science related curricula. Conditional to our sample, the mean WTP for the LHC was calculated to be as about EUR 7.7 per person una tantum. This amount is relatively small compared, for example, to CV results of e.g. Hansen (1997), Pollicino and Maddison (2001) and Alberini and Longo (2006) for cultural goods, but we do not claim that our survey is representative of the general population attitudes. Actually, we were interested to perform an exploratory analysis of the drivers of social attitudes towards science leading to a positive willingness-to-pay for it, and our findings point to such evidence.

The willingness-to-pay for science is, as expected, fuelled by income, i.e. the greater the income, the more likely is the probability to observe a *'yes'* response (but our sample didn't provide support for a correlation between income and the level of the bid); by being interested in scientific research in general; by having a positive attitude toward science; and finally, by having heard what CERN and the LHC are. The latter drivers strongly point to the role of outreach of science and propagation effects through the media. These determinants matter independently from the way the WTP is asked, specifically either by asking for a periodic payment of a money amount or by asking to pay it at once.

We conclude with some caveats and indications for future research. We guess that the estimated mean WTP in the sample is likely to be on the lower bound of the actual distribution in the general population because the WTP questions in our survey open up for anchoring with a rather low maximum. However, the results are not negligible when one considers that, given the international scope and public good nature of Big Science, even a small individual WTP would potentially apply to a very large population. Further research should target a representative sample of taxpayers in the countries supporting large scale RIs (for example the CERN Member States).

While the estimation of non-use value of RIs is still in its infancy, the approach tried in this study to elicit the WTP was a CV experiment, which is a well-established in environmental and cultural economics. Hence, we see scope for replication in other contexts. Moreover, one may think that there is some scope for testing the WTP in this field by stated choice experiments, which have become more popular in recent years (DeShazo and Fermo, 2002; Scarpa, 2008). For example, one may consider the different possible features in the design of a proposed Big Science project, before its actual implementation, such as the Future Circular Collider[30], proposed by CERN to start around 2040. This is left to future research.

Finally, the policy implications of our study are potentially important, when one considers that taxpayers are required to support Big Science and, until now, little is known about their willingness-to-pay for it.

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